

IN-51-CR

FINAL TECHNICAL REPORT

203546

Grant Title: Skeletal Muscle Metabolism in Hypokinetic Rats

10 p

Grant numbers: NAGW-227 (July 1981 - October 1985);  
NAG2-384 (November 1985 - December 1993)

Period of Report: July 1981 - December 1993

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Date: 1/31/94

(NASA-CR-195082) SKELETAL MUSCLE  
METABOLISM IN HYPOKINETIC RATS  
Final Technical Report, Jul. 1981 -  
Dec. 1993 (Arizona Univ.) 10 p

N94-24124

Unclass

G3/51 0203546

This grant focused on the mechanisms of metabolic changes associated with unweighting atrophy and reduced growth of hind limb muscles of juvenile rats. Metabolic studies included a number of different areas. Amino acid metabolic studies placed particular emphasis on glutamine and branched-chain amino acid metabolism. These studies were an outgrowth of understanding stress effects and the role of glucocorticoids in these animals. Investigations on protein metabolism were largely concerned with selective loss of myofibrillar proteins and the role of muscle proteolysis. These investigations lead to finding important differences from denervation and atrophy and to define the roles of cytosolic versus lysosomal proteolysis in these atrophy models. A major outgrowth of these studies was demonstrating an ability to prevent atrophy of the unweighted muscle for at least 24 hours. A large amount of work concentrated on carbohydrate metabolism and its regulation by insulin and catecholamines. Measurements focused on glucose transport, glycogen metabolism, and glucose oxidation. The grant was used to develop an important new *in situ* approach for studying protein metabolism, glucose transport, and hormonal effects which involves intramuscular injection of various agents for up to 24 hours. Another important consequence of this project was the development and flight of Physiological-Anatomical Rodent Experiment-1 (PARE-1), which was launched aboard space shuttle Discovery in September 1991.

Detailed descriptions of these many studies can be found in the 30 peer-reviewed publications, 15 non-reviewed publications, 4 reviews and 33 abstracts (total 82 publications) which were or are scheduled to be published as a result of this project. These publications grouped by area (i.e. amino acid metabolism, protein metabolism, carbohydrate metabolism, and space flight studies) are found on the following pages in chronological order.

## Amino Acid Metabolism

1. **Tischler ME**, Jaspers SR (1982) Synthesis of amino acids in weight bearing and non-weight bearing leg muscles of suspended rats. *Physiologist* **25**:S155-S156.
2. **Tischler ME**, Jaspers SR, Fagan JM (1983) Prevention of metabolic alterations caused by suspension hypokinesia in rats. *Physiologist* **26**:S98-S99.
3. **Tischler ME**, Jaspers SR, Fagan JM (1983) Prevention of metabolic alterations caused by suspension hypokinesia in leg muscles of rats. IUPS - Gravitational Physiology Symposium, Moscow, USSR. (Abstract)
4. **Tischler ME**, Jaspers SR (1983) Metabolic alterations caused by suspension hypokinesia in leg muscles of rats. Space Biology Symposium. (Abstract)
5. Jaspers SR, **Tischler ME** (1984) Regulation of glutamine production in soleus muscles from hypokinetic/hypodynamic rats. *Fed Proc* **43**:1549. (Abstract)
6. Jaspers SR, Jacob S, **Tischler ME** (1986) Metabolism of amino acids by the atrophied soleus of tail-casted, suspended rats. *Metabolism* **35**:216-223.
7. **Tischler ME**, Henriksen EJ, Cook PH (1988) Role of glucocorticoids in increased muscle glutamine production in starvation. *Muscle Nerve* **11**:752-756.
8. Jaspers SR, **Tischler ME** (1988) Insulin effect on amino acid uptake by unloaded rat hindlimb muscles. *Horm Metab Res* **20**:125-126.
9. **Tischler ME**, Henriksen EJ, Jacob S, Satarug S, Cook PH (1988) Problems in analysis of data from muscles of rats flown in space. *Physiologist* **31**:S10-S13
10. Jaspers SR, Henriksen EJ, Jacob S, **Tischler ME** (1989) Metabolism of branched- chain amino acids in unloaded leg muscles from intact and adrenalectomized rats. *Metabolism* **38**:109-114.
11. Jaspers SR, Henriksen EJ, Satarug S, **Tischler ME** (1989) Effects of stretching and disuse on amino acids in muscles of rat hind limbs. *Metabolism* **38**:303-310.

## Carbohydrate Metabolism

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2. Henriksen EJ, **Tischler ME** (1985) Possible mechanism for changes in glycogen metabolism in unloaded soleus muscle. *Physiologist* **28**:S131-S132.
3. Henriksen EJ, **Tischler ME** (1985) Effect of disuse on carbohydrate metabolism in muscles from suspended rats. *Fed Proc* **44**:1391. (Abstract)
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5. Henriksen EJ, **Tischler ME** (1986) Characterization of the diminished capacity for glucose uptake in the 24 hr unloaded soleus. Abstracts for Annual Meeting ASGSB 2:43. (Abstract)
6. Henriksen EJ, **Tischler ME** (1987) Acute unloading of the soleus results in a diminished capacity for glucose uptake. *Fed Proc* **46**:326. (Abstract)
7. Henriksen EJ, **Tischler ME** (1987) Recovery of glycogen following short-term unloading of the rat soleus muscle. *ASGSB Bull* **1**:23. (Abstract)
8. Kirby CR, Henriksen EJ, Cook P, **Tischler ME** (1987) Metabolic response of skeletal muscle to isoproterenol following unloading or denervation. *ASGSB Bull* **1**:23. (Abstract)
9. Henriksen EJ, **Tischler ME** (1988) Time course of the response of carbohydrate metabolism to unloading of the soleus. *Metabolism* **37**:201-208
10. Henriksen EJ, **Tischler ME** (1988) Regulation of skeletal muscle glucose uptake: effect of acute unloading and subsequent reloading of the rat soleus muscle. *J Appl Physiol* **64**:1428-1434.
11. Henriksen EJ, Kirby CR, **Tischler ME** (1989) Glycogen supercompensation in rat soleus muscle during recovery from non-weight-bearing. *J Appl Physiol* **66**:2782-2787.
12. Kirby CR, Henriksen EJ, Hartshorne WJ, McCready SM, **Tischler ME** (1989) Fractional activities of glycogen synthase and phosphorylase during recovery of the 72-hour unloaded soleus. *ASGSB Bull* **2**:56. (Abstract)
13. Kirby CR, **Tischler ME** (1990) Beta-adrenergic effects on carbohydrate metabolism in the unweighted rat soleus muscle. *J Appl Physiol* **69**:2113-2119.
14. Kirby CR, **Tischler ME** (1990) Receptor and post-receptor stimulation of cAMP production in unweighted and denervated soleus. *ASGSB Bull* **4**:63. (Abstract)
15. Kirby CR, Woodman CR, Woolridge D, **Tischler ME** (1991) Unweighting but not denervation increases muscle hormone sensitivity in vitro and in vivo. *ASGSB Bull* **5**:36. (Abstract)

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## Protein Metabolism

1. Jaspers S, **Tischler ME** (1982) Correlation of quantity and the metabolism of protein in hindlimb muscles of hypokinetic rats. *Fed Proc* **41**:867. (Abstract)
2. Jaspers SR, Fagan JM, **Tischler ME** (1983) Effect of limb immobilization on protein turnover and redox state in muscles of hypokinetic rats. *Fed Proc* **42**:1815. (Abstract)
3. Fagan JM, **Tischler ME** (1983) Protein degradation and redox state in leg muscles of diabetic rats. *Fed Proc* **42**:1815. (Abstract)
4. Jaspers SR, **Tischler ME** (1984) Atrophy and growth failure of rat hindlimb muscles in tail-cast suspension. *J Appl Physiol* **57**:1472-1479.
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10. Henriksen EJ, **Tischler ME**, Jacob S, Cook PH (1985) Muscle protein and glycogen responses to recovery from hypogravity and unloading by tail-cast suspension. *Physiologist* **28**:S193-S194.
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12. Jaspers SR, **Tischler ME** (1986) Role of glucocorticoids in the response of rat leg muscles to reduced activity. *Muscle Nerve* **9**:554-561.
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17. **Tischler ME**, Eisenfeld S, Rosenberg S, Henriksen EJ (1986) Role of lysosomal proteolysis in soleus muscle atrophy by unloading. Program for Annual Meeting ASGSB 2:43. (Abstract)
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29. Kirby CR, **Tischler ME** (1989) Evidence for sparing of membrane proteins during atrophy of unweighted rat soleus. ASGSB Bull 3:87. (Abstract)
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32. Springer L, Kleiner D, Kirby C, **Tischler ME** (1990) Alterations in muscle membrane enzymes during disuse atrophy. *ASGSB Bull* **4**:64. (Abstract)
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34. Munoz KA, **Tischler ME** (1991) A novel approach to measuring in vivo protein synthesis. *ASGSB Bull* **5**:55. (Abstract)
35. **Tischler ME**, Henriksen EJ, Munoz KA, Stump C, Woodman C, Kirby CR (1992) Spaceflight effects on muscle protein and soleus muscle response to insulin. World Space Congress, Washington, DC. (Abstract)
36. **Tischler ME** (1992) Estimation of protein synthesis and proteolysis in vitro. In: Modern Methods in Protein Nutrition and Metabolism (Nissen S, ed.), Academic Press, San Diego, pp. 225-248.
37. Munoz KA, Satarug S, **Tischler ME** (1992) Time course of the response of myofibrillar and sarcoplasmic protein metabolism to unweighting of the soleus. *ASGSB Bull* **6**:34. (Abstract)
38. Isaias T, Truesdell M, Rodriguez S, **Tischler ME** (1992) Effects of modified gravitational orientation on adult development of Manduca sexta. *ASGSB Bull* **6**:46. (Abstract)
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40. Henriksen EJ, Munoz KA, Aannestad A, **Tischler ME** (1993) Effects of unweighting on protein content and in vivo protein synthesis in skeletal muscles of trained vs. sedentary rats. *ASGSB Bull* **7**:48. (Abstract)
41. Munoz KA, Aannestad A, **Tischler ME**, Henriksen EJ (1994) Skeletal muscle protein content and synthesis after voluntary running and subsequent unweighting. *Metabolism*, in press.
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43. **Tischler ME** (1994) Effect of the antiglucocorticoid RU38486 on protein metabolism in unweighted soleus muscle. *Metabolism*, in press.



## Space Flight Studies

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## Reviews

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2. Morey-Holton E, **Tischler ME** (1988) NASA Workshop on Biological Adaptation. NASA Technical Memorandum 89468.
3. **Tischler ME**, Kirby CR (1991) Space Travel (Biochemistry and Physiology). In: Encyclopedia of Human Biology, Vol. 7 (Dulbecco R, ed.), Academic Press, New York, pp. 143-152
4. **Tischler ME**, Morey-Holton E (1993) Space research on organs and tissues. NASA Technical Memorandum 4502.